CARNOTITE

The Principal Source of Radium

BY

THOMAS F. V. CURRAN

1913.

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171 WEST 10th ST.
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DEALERS IN

RADIUM PRODUCTS, RADIO ACTIVEORES,
CARNOTITE, VANADIUM,
URANIUM ORES AND RARE MINERALS

CARNOTITE.

By Thomas F. V. Curran.

Carnotite is probably an alteration product of pitchblende and is the mineral whence the major portion of the radium supply is derived.

HISTORY.

It was discovered by Charles Poulot, late in 1887 or early in 1888, along Roc Creek (or possibly La Sal Creek) Western Montrose County, Colorado. In the beginning small lots were shipped to a little wooden shed near the east end of Champa Street, Denver, where the ore was treated by Poulot and E. Cumenge, chemists associated with M. Voilleque in the rare metals business in Denver.

Poulot traveled extensively through Colorado and acquired a pitchblende deposit in Gilpin County, which he sold to Roman Catholic Bishop Macheboeuf of Denver; the latter died in 1890 and bequeathed it to his successor, Bishop Matz, who sold it in 1912 to Senator Dupont for $10,000. Poulot was interested also in the Tungsten deposits of Boulder County.

The business was kept quite secret; however, Rev. A. W. Forstall, S. J., professor of chemistry of College of the Sacred Heart, Denver (which college opened in 1888), soon became acquainted with Poulot and helped in some of the analytical work on the ores.

The Uranium-Vanadium mineral was named Carnotite, in 1888, by Mr. Poulot, at the suggestion of Mr. Cumenge, in honor of Marie Francois Sadi Carnot, who was born at Limoges in 1837, became President of France Dec. 3, 1887, and died (assassinated) at Lyons in 1894. He was a graduate of the Stud. Politechnique, and a modest scientist until the national catastrophe of 1870 caused him to enter politics as a duty to France.

The ore was treated in such manner as to produce a crude form of combined oxides of Uranium and Vanadium, and shipped to France. There the Vanadium was extracted and used in the South of France for coloring fine silks, while the Uranium content was used in tinting of porcelains, glass, etc. It is supposed that the Rothschilds of St. Denis (France) were in some way connected with the business.

In the spring of 1899 Poulot built a small three stage mill in the McIntyre mining district of San Miguel County, along the Dolores river, and operations were placed in charge of M. M. C. Freidel and E. Cumenge. The upper stage of the mill contained a large floor for storing ore, also the feeder of a ten-ton Krupp ball mill. The second stage held three low leaching tanks, each about 10 feet in diameter, a Krupp ball mill, a 30 horse-power upright boiler and a 10 horse-power upright engine. The lowest stage contained one low and three high precipitation tanks and a small chemical laboratory. The total cost of the mill was about $8,000. The ore milled aggregated about 355 tons; the output of Uranium oxide 15,-000 pounds. Work was abandoned in the summer of 1901.

In the fall of 1902 experiments were conducted on several tons of low grade ore, but discontinued a few months later and were not resumed.

In the spring of 1903 a concern known as Western Refining Co. used the Engle-Haynes extraction process and milled about 140 tons of ore, obtaining about 2,500 pounds of Uranium concentrates. The same process was employed in 1905 by the Dolores Refining Co., which erected a mill about a mile from the old mill. Its period of operation was brief. Recently this process, only slightly modified, has been patented in this country, but not by its originators.

Thereafter the Carnotite industry was dormant until the fall of 1909, when the General Vanadium Company of America, of Baltimore, purchased and began operating a number of prospects along the south side of the East Paradox Valley; among these were such well-known producers as the Jodandy, Canary Bird, Blackburn, Hummer and Valley View lodes; initially, all were operated for the Vanadium values of the ore. Early in 1910 the writer induced Radium makers in England, France and Germany to experiment earnestly with Carnotite; a strong and steady demand soon was developed for Carnotite for Radium extraction.

NATURE.

Carnotite is a canary yellow powder, or slightly cohering mass or yellow stain in rock crevices or in sandstone and composed principally of potassium uranyl vanadate and small quantities of barium and calcium. (Potassium has a specific radio-activity, although it seems to emit only Beta rays of pen-

etrating power about equal to those of Uranium, but of electrical effect of only about 1/1000 of the Uranium Beta rays.) Sometimes the Uranium values are in the form of a finely pulverulent carnotite filling the interstices of soft grey sandstone; at others it may be encountered as an impregnation permeating even the sand particles. The sandstone varies in texture and hardness, from extreme coarseness to the opposite; sometimes it is very hard, though usually it is soft and friable.

Siegfried Fischer says "Absolutely pure carnotite is exceedingly hard to obtain, due to its nature and occurrence. While many chemical formulas have been given to it, none of them has been definitely accepted. However, it seems to be established that it is a vanadate of uranium and potassium. The complexity of carnotite will be shown best by quoting two complete analyses by W. F. Hillebrand:

	Per cent.	Per cent.
UO_3	54.89	54.00
P_2O_5	0.80	0.05
As_2O_3	Trace	None
Al_2O_3	0.09	0.29
V_2O_5	18.49	18.05
Fe_2O_3	0.21	0.42
CaO	3.34	1.86
SrO	0.02	Trace
BaO	0.90	2.83
MgO	0.22	0.14
K_2O	6.52	5.46
Na_2O	0.14	0.13
Li_2O	Trace	Trace
H_2O, 105°	2.43	3.16
H_2O, 350°	2.11	2.21
PbO	0.13	0.07
CuO	0.15	Trace
MoO_3	0.18	0.05
SiO_2	0.15	0.20
TiO_2	0.03	?
CO_2	0.56	None
Insoluble	7.10	10.33
	98.46	99.25

Here a word may be said as to Uranium, the most important constituent of Carnotite. Uranium is silver white when fused, grey black when powdered, somewhat malleable and nearly as hard as steel. It oxidizes in air more vigorously upon heating and is soluble in dilute sulphuric acid and hydrochloric acid. Its principal oxide is $U_3 O_8$, which is soluble in hydrochloric, sulphuric and nitric acids; contains 84.85% Uranium. S. G. 7.193. Uranium compounds were first isolated by Klaproth in 1789 out of pitchblende and autinite. The metal was isolated in 1840 by Peligot. Radio-activity in Uranium was discovered by Bequerel in 1896. Radium was isolated in 1908 by Professor and Mme. Curie.

OCCURRENCE.

As to the better known Carnotite ore formations. The Dolores, or red beds, are the lowest formation visible in the canyons, which are followed by the La Plata sandstones, above which occurs a series of thin bedded sandstones with shales, this strata being practically horizontal, and contains the Carnotite. Sometimes conglomerates are found in this strata, though rarely, and apparently foreign to the strata. The elevation above sea level of the highest determined mine is 6,700 feet; it may be noted that the Carnotite deposits along Atkinson Creek, only about eight miles north from this mine, are only 5,400 feet above sea level, and there are mines in Utah as low as 4,500 feet above sea level.

So far as investigation has progressed, it is safe to say that the best Carnotite deposits are in Colorado, and are found in Western Montrose County, in Long Park, Bull Canyon, Jodandy Hill, Club Ranch, Hydraulic, Atkinson Creek, Tabequache Creek, Lion Creek, Roc Creek; deposits occur also in Mesa County, near Gateway; in San Miguel County in the McIntyre mining district, near Cedar; also in Dolores, Routt and Rio Blanco Counties. In Utah the ore is found in Grand, Emery and San Juan Counties. It occurs also at Radium Hill, near Olary, in the Flinders Range of South Australia, and in Central Turkestan, and is reported in Spain and near Guarda, Portugal.

The extent of the American Carnotite field is very large, probably several thousand square miles; the writer has examined considerable of this large region, but generally has found the ore in small patches only and of a grade less than

one per cent. U_3 O_8, with the exception of a small section bounded on the north by the La Sal mountains, along La Sal Creek, and on the south by Big Canyon, which is about three miles north of "The Glades" ridge in San Miguel County, which latter contains a very thick deposit of bituminous coal. The commercially important deposits in this small area, which is only about 50 miles long and not over 15 miles wide, are not numerous, and it is obvious that the practice of skimming off and shipping only ores running over 2 per cent. U_3 O_8 content cannot continue long.

The Paradox Valley, closely associated with the recent history and occurrence of Carnotite, is a basin (that may have been the bed of a sunken lake), about three miles wide and twenty-eight miles long, nestling at the bottom of the jagged, scarred and eroded mesa ranges, reaching above the valley about 1,700 feet. The entrance is made as the stage road turns over the western brow of Coke Ovens Hill, six miles west of Naturita. (Coke Ovens Hill contains deposits of coking coal and here coke was made some years ago for the smelter of the locally famous Cashin copper-silver mine, on La Sal Creek, 22 miles westerly.) Two or three miles from this entrance point, the wagon road to Long Park debouches northwesterly, ascending the mesa's foothills five miles, thence Long Park stretches in a shallow basin six miles, merging into the series of corrugated ridges and canyons, beginning with Hieroglyphic Canyon, and ending at Saucer Basin, that ensue until the Dolores river is reached seven miles west at its juncture with the Rio San Miguel.

Bisecting the Paradox Valley, the sluggish Dolores river wends its serpentine way in a northerly direction, following the course of the high snowclad La Sal mountains that form the western end of the valley. Since the valley proper runs easterly and westerly, or at right angles to the course of the river, the valley is called "Paradox." In passing it may be observed that the general direction of Paradox Valley is practically the same as the San Miguel river, which empties into the Dolores near Hydraulic. Many theories are advanced as to the formation of this valley, one being that the mesa at one time extended from Long Park across what is now the valley to the top of Jodandy Mine Hill or the Monogram Flat, that internal gases caused it to raise into a low ridge, and upon the

subsidence of these gases the ridge became a valley with abrupt, sheared sides. The upward tilt, of about ten degrees, to the sandstone formation towards the valley, from both its north and its south side, is pointed out. Another theory is that tremendous erosion resulted in the valley, but the formation makes this improbable. In the McIntyre district there are evidences that the old bed of the Dolores was about 800 feet above its present bed, and, as a rule, 800 feet—is the mean elevation of Carnotite beds above the existing river beds. No topographical map has been made of the Carnotite ore belt, and without it little progress will be made in the study of this formation.

The ore extracted from the Carnotite deposits on the south side of the valley is packed on burros to the stage road, at a cost of about two dollars per ton. Here are situate the "Monogram" group of claims, owned by a Pittsburgh concern; this group consists of possibly thirty claims; the ore is found under a cap of rock usually not more than ten feet thick, and this underlying a few feet of surface soil. The quality of the ore is fairly good, and the quantity satisfactory. The ore must be hand-picked carefully to yield an average shipping grade of two per cent., $U_3 O_8$. (However, this observation can be made truthfully of all other deposits, except of some solution-enriched pockets of ore that may be encountered here and there in the Carnotite region.) To the east is found the Jodandy group of about ten claims, and the Thunderbolt group; all these show the effect of the "skimming" and "gophering" mining that has been practiced. Indubitably, under a wise trade policy practically all the ore found on these mine dumps would have been shipped and yielded the shipper a fair profit.

As has been said before, the north side of Paradox Valley is the flat basin known as Long Park, which latter is enclosed in saw-tooth hills that rise some three hundred feet above the basin floor. The south border of this basin is the upper ridge of the northern wall of Paradox Valley. The northern boundary merges into the sloping south canyon walls of the swirling, rushing San Miguel river, one of the swiftest streams in the West. Running stringer-like from the south rim of Long Park basin in a northeasterly direction are the hog-backs that contain the Carnotite. Practically all these have strata of the yellow ore, dipping towards the San Miguel river, some three

GENERAL VIEWS OF THE CARNOTITE COUNTRY

miles northeasterly and a thousand feet below. The prominent Carnotite claims are the Maggie C, which is patented, the Swindler, Cripple Creek, Hope, Media, Jack Angle, Park Nos. 1, 2 and 3, the Great Western, Honeymoon, Vanadate, Bryan, North Star, Sunday and Nucla; all are connected by wagon road to the Paradox Valley stage road. The trip may also be made by automobile.

The west border of Long Park is, as has been stated, Hieroglyphic Canyon, which ends at the San Miguel river near Club Ranch. Various claims are scattered along the Canyon walls, and upon the flat bench overlooking the south side of the San Miguel river is situate the "Yellow Jacket" group, that shows an apparent abundance of the yellow ore under a cap of rock and earth usually not more than four feet. Again, the ore must be hand sorted to yield an average of 2 per cent. $U_3 O_8$. On the north side of the San Miguel river are several prospects that should be of the same character as the Yellow Jacket group, but little work has been done, however. About a mile further down the river and on the same or north side, is Atkinson Creek, and here considerable prospecting has been done. The "Big Mitt" that lies for 1,500 feet along the bench above the west bank of the creek, has had the ore exposed in eight places. The "Ruth Ellen" shows in the location shaft several feet thickness of ore averaging much higher than ordinary shipping grade. The "Club No. 2" also shows excellent ore along the outcrop for several hundred feet. Further south and west, across the San Miguel river, is Saucer Basin, which is at the juncture of the Dolores and the San Miguel. Here is the "Cliff" claim, one of the best producers in the whole Carnotite region, with apparently not another Carnotite claim within several miles.

Along the west bank of Dolores river are a number of claims that are being developed and from which several carloads of ore have been shipped. On this side also is Roc Creek, along the top of which is Carpenter Flats, where the ore may be found at the very grass roots in the "Park Belle" claim. Here also are Yellow Liner, Yellow Clara, Yellow Cycle and Olympic Lodes. Along Lion Creek are the "Confusion," Vista Grande, Lion Creek and Canyon View, which all have been developed enough to show them as of importance. Along La Sal Creek is the "Yellow Bird" group,

famous in Poulot's day, and further south the "Kent" and "Bonanza" claims, the first named in honor of the great English vanadium authority, J. Kent Smith, and which shows a tunnel some 70 feet long cut the entire distance through a 3-foot thick blanket of Carnotite ore.

Bull Canyon has about 40 claims. This region is much eroded, the sandstone is very hard, and the ore strata quite irregular and pockety, but with good bunches of ore showing occasionally. The Batchelor group and the Black Fox may be mentioned, as also the Wedding Bell and the Sunrise.

A few miles south of Bull Canyon, along the Dolores river, are found the Stephens mines, which are on flat benches akin to the "Yellow Jacket" bench along the San Miguel river. From one of these benches several carloads of Carnotite of grade averaging more than 3% U_3O_8 has been taken. The occurrence seems to be in the bed of an ancient creek, and in a pay-stratum of about one foot thick. Overlying this was a blackish-grey stained sandstone layer three feet thick, and above it a continuation of the same layer, but not stained, of about two feet, this latter being at the surface. Some three miles south is Big Canyon, along which are some 40 claims belonging to the owners of the new Uranium mill on the banks of the Dolores, the American Rare Metals Co., and to a number of individual owners. The ore here seems much admixed with carbon from the immensely thick deposits of coal in the "Glades," a portion of which would naturally drain into this region. In Uranium content this ore will average not quite one per cent. Sixteen miles northwest of Monticello, San Juan Co., Utah, is the Dry Valley district, in which a number of claims have been located; this region is especially arid; conflicting tales are told by prospectors, the most glowing being that the region is somewhat like the Paradox region in the quality and quantity of the ore, but water is very scarce and the railroad one hundred miles away, while in the Paradox the average distance of deposits from the railroad is about 60 miles. Little space need be taken in describing the Green River deposits, nor those of Temple Rock, Utah, 45 miles south of Green River. Torn and dishevelled as the Colorado Carnotite fields undoubtedly are, they are regular and orderly compared with the tumbled masses of baked and parched lava, mud, rock and alkali that compose the Utah deposits. Ten

miles from Green River Station, one of these deposits is found, with the ore in a coarse iron-specked sandstone, not in horizontal beds as in the Paradox, but in tiny stringers running from the surface with a 60-deg. dip, to a depth of six or ten feet, and ending abruptly. Very little systematic exploration work has been done. The Cisco deposits are even worse. Those below Thompson, Utah, near the Colorado border, should offer better promise of stratum uniformity, hence of finding profitable Carnotite deposits.

MINING COSTS.

Taken as a whole, it should be reiterated that the Carnotite ore resources are important commercially, but that they are extremely limited if measured in their capacity to produce, say 150 tons per month of ore averaging not less than 2% Uranium Oxide content. At present four tons of what should be shippable grade ore are thrown on the waste dump for every ton of ore that is shipped. The average cost of mining and sacking 2,000 pounds of Carnotite ore is $32.00, and this does not take account of mine depreciation, as it certainly should be made to do. The sacks cost $3.50 to $4.50 per ton of ore, the wagon hauling $20.00 per ton, the packing from many of the mines to wagon road costs $7.50 per ton, and the freight to Galveston from Placerville costs $9.50 per ton. If the ore is sampled in Denver $1.00 additional should be added to freight charge, and $3.50 to $6.00 per ton for sampling charge. The freight to European ports is from $3.60 to $5.00 per ton. The usual price paid for this ore has been about $2.00 per pound U_3O_8, and when mesothorium seemed to frighten the radium makers the early part of 1913, and the price of radium bromide dropped from $71 to $69 per milligram, they began immediately to slash the price paid to the ore supplier for Carnotite, notwithstanding that the latter had received from the ore buyer only about eight per cent. of its contained values in Radium, Vanadium and Uranium. Since then the price of radium bromide has advanced tremendously, some quotations being $100 per milligram, but, strange to say, the radium-makers seem to think there is now very little relation between the selling price of radium bromide and the price they wish to pay for Carnotite. Nevertheless, they are dependent upon Carnotite for their radium output!

ORE PRODUCTION.

The Carnotite shipped from the Paradox in 1911 aggre-

gated 1,515 tons containing 26 tons of Uranium; in 1912 the output was 1,092 tons containing 22 tons Uranium. The decrease was due partly to inactivity of two corporate operators during part of 1912, and also partly because many of the rich surface "pockets" of Carnotite had been worked out and much exploration work was necessary. The output for 1913 will be about 1,200 tons, containing about 25 tons Uranium. If the mining is pushed energetically in 1914, the output should be about 2,000 tons, containing 40 tons Uranium. In order to produce Carnotite steadily and regularly, exploration and development work must be kept in advance of actual mining operations, and must be regarded as of prime importance. And this must, necessarily, affect the price of the ore.

ORE VALUES.

As has been stated already, Carnotite contains three valuable constituents, namely, Vanadium, Uranium, and Radium.

Vanadium.

Vanadium has a multitude of uses, its chief use being as an alloy of iron, steel, copper and bronze, wherefore it is in much demand. Its effect in well deoxidized metals is: (1) About one-fifth of the alloy that is added to the metal, automatically scavanges the molten mass of nitride and oxide gases, which gases are poisonous and cause the minute holes from which rupture arises; (2) one-half of the remainder of the alloy unites with the carbonless portion of the metal, called ferrite, and toughens it still more; and (3) the balance of the alloy acts upon the carbides, strengthens them, and distributes them evenly. Hence, Vanadium-treated metals are uniform, close grained, tough and strong, and attain the maximum in economy, safety and endurance. The cost of reducing ordinary vanadium oxide to ferro-vanadium is about 68 cents per pound of vanadium metal contents; the market price of ferro-vanadium is $2.50 per pound vanadium contents.

Vanadium medicines are made and marketed by a Pittsburgh concern; their therapeutic value is more than doubtful.

Experiments are being made with Vanadium as a catalyzing agent in soils for the purpose of attracting nitrogen and hastening plant growth.

Uranium.

In the form of Sodium Uranate, Uranium is used for tinting glass, porcelain, and ceramics. In rich coloring, the Ura-

of the glass. Naturally such glass is highly radio-active. The price of Sodium Uranate is from $2.70 to $3.50 per pound, according to its purity or freedom from Vanadium. Its reduction cost is about 90 cents per pound.

E. de Haen, of Hanover, Germany, advertises ferro-uranium at a price of about $50 per pound, indicating very limited use. A Sheffield steel maker, a few years ago, used a complex Portuguese ore containing Uranium in making steel for the British Admiralty. The static and dynamic properties nate addition is sometimes as much as 25% of the weight were claimed to be so wonderful that the concern spent $60,000 in trying to produce another heat of Uranium Steel, but in vain.

The filament of the Madza Anyangle incandescent electric light is made of Uranium.

OTHER RADIUM ORES.

However, Carnotite and Pitchblende are not the only minerals containing Radium. Under caption "Uranium Ores in Portugal, the "Mining World" (London) says: "It has now, however, been proved that Autunites (Uranium ores from Guarda, Portgual,) can successfully compete with pitchblende; that the known deposits of pitchblende are not sufficient to cope with the world's present demand for radium, even were all available ores placed on the market at once; that the most suitable ores for the extraction of radium are autunites; that the only known, exploited deposits of autunites are in Portugal; and whatever the output, the increasing demand throughout the world for this mineral can never be supplied; that the average value of a 1% autunite ore is £30, or at $4.85, $145.80, per ton, and that there is practically a free market." Commenting, it may be observed that representative samples of this ore gave Uranium values varying from 0.18% to 2.5%, with an average of 0.5%, and even this low average has been attacked by an autunite mine shareholder as too high.

The Australian Carnotite is little more than an incrustation and powder on the faces, joints and crevices of a lode formation, which consists of magnetic titaniferous iron, magnetite, etc., and quartz in association with black mica (biolite). Practically all the secondary Uranium minerals are encountered, such as:

Torbenite—(Copper Uranium Phosphate).

Autunite—(Calcium Uranium Phosphate).
Uranophane—(Hydrous Uranium-Calcium Silicate).
Carnotite—(Potassium-Uranium Vanadate).
Fergussonite—(Niobates of rare earths, Uranium, etc.).
Gummite—(Hydrous Oxide of Uranium).
Uranium Ochre, Monazite, etc.

In the treatment of these ores, a preliminary leach of sodium carbonate solution is recommended by Dr. Douglas Mawson, for the Australian Ministry of Mines, who is of opinion that primary Uranium minerals will be found at depth, such as Pitchblende. The prominence given to the "Vughs lined with crystallized quartz, often amethystine or smoky," as a feature of the Mount Gee portion of the lode, recalls the characteristic feature of the "Old Mexico" group of claims in Bull Canyon, also the Sundown, Uranium Bell, and Batchelor group. Vughs filled with high-grade Carnotite are frequently encountered in Long Park, but the lining is very soft, almost decomposed, and probably are only old water courses.

Little is known of the Turkestan Carnotite; it is said to be low grade, not over 0.5% Uranium Oxide content.

RADIO-ACTIVITY OF ORES.

Rutherford and Soddy early suggested that radium is a disintegration product of one of the radio-active substances present in pitchblende, and from the fact that radium and Uranium are always found together that probably Uranium is the primary source of radium. If so, the amount of radium in a mineral always should be in a constant ratio to the amount of Uranium. This question was attacked experimentally by Boltwood, McCoy and Strutt, and the results obtained afford a direct and satisfactory proof that the amount of radium is directly proportional to the amount of Uranium. The amount of radium per gram of Uranium was found to be 3.4×10^{-7} gram. Consequently one gram of radium element is present in a mineral containing 3,000 kilos (2.2046 pounds in a kilo) of Uranium. This means that 2,000 pounds of Uranium (metal) contains 330.64 milligrams of Radium element. (See "Radio-active Substances and their Radiations," Rutherford, 1913.)

ORE VALUES.

Rutherford gives the radio-activity of

Pitchblende, Joachimsthal	3.21×10^{-7}
Autunite, Autun	2.56

Carnotite, Colorado 2.34

In comment, it should be pointed out that this latter could not have been a representative sample of Carnotite, otherwise the figure should have been 2.9×10^{-7}.

Mme. Curie, using the electrical method (current was measured between two parallel plates, 8 cms. in diameter and 3 cms. apart, when one plate was covered with a uniform layer of the active matter in a powdered state), made the following determinations, the numbers giving the order of the saturation, or maximum, current in amperes:

Pitchblende from Johanngeorgenstadt	8.3×10^{-11}
Pitchblende from Joachimsthal	7.0
Pitchblende from Pzibram	6.5
Pitchblende from Cornwall	1.6
Chalcolite	5.2
Autunite	2.7
Thorite	0.3 to 1.4
Black Oxide of Uranium	2.6
Carnotite, Colorado	6.2

Recent determination of the ratio of Radium element to the Uranium content of the ore, in average grade Colorado Carnotite, compared with St. Joachimsthal pitchblende, adopting the latter as standard equilibrium, or 100%, give the Carnotite 91%. On this basis, Mme. Curie's figures give the comparative Ra/U ratio, for Carnotite, as almost 89%. A detailed report from authoritative sources will be published soon. The ores examined so far are all from the Long Park district.

Two methods may be employed for examination of radiation of Carnotite ore (1) Photographic Plate, and (2) Ionising action of rays on surrounding gas, i. e., by electroscope.

The photographic method has been displaced by the electrical method, because it usually takes a day's exposure to appreciably darken the film, and this darkening may be produced by rays not proceeding from the Uranium constituent of the ore. Again, the thickness and rapidity of the films used affects the photographic effect of the different types of radiations. However, this method is valuable in investigating curvature of the path of the rays when deflected by a magnetic field.

The electrical method is a rapid and accurate means of quantitatively examining the radiations over wide range, from

extremely small intensity to very high intensity. As radium is manifested principally through its electrical properties, a few remarks as to how this effect is measured may interest.

The radiations from Uranium and other radio-active matter possess the property of discharging, or emitting, at great speed, electrified particles (whether the same be charged positively or negatively). These rays produce positively and negatively charged carriers (called ions) throughout the volume of the gas surrounding the charged body, and the rate of production is proportional to the intensity of the radiation; while under a constant electric field these ions move through the gas with a uniform speed, this varying directly as the strength of the field. In the electric field, the positive ions travel towards the negative plate, and the negative ions towards the positive plate, causing a current through the gas. In a weak electric field, the ions take so long to travel between the electrodes that most of them recombine on the way. With increase of voltage, the ions move faster and a small number recombine. This results in an increase of the current and this reaches full value (called "saturation" current) when the electric field is strong enough to remove all the ions before appreciable recombination has taken place, and the value of this current will remain constant even though the voltage be largely increased.

Samples of seventy-five Paradox Valley Carnotite ore shipments were assayed for Uranium Oxide contents by one of the best known English analysts, and his results were checked, on the electroscope, by a prominent physicist. In 72 the figures tallied within 5% error allowance, and in all three differences the analyst was in error. This seems to demonstrate not only the remarkable accuracy of the electroscope, but also that the ratio of radium to uranium in these Carnotite ores is a constant ratio.

METALLURGY OF CARNOTITE.

The extremely fine state of division of Carnotite precludes successful ore dressing. Magnetic experiments have been unsuccessful. A method of sliming and subsequent attrition whereby the values, in the form of slimes, might be filter pressed or settled, lost one-third of the contained values. Crushing the ore and subsequent screening dry, gave negative results on works' scale, although preliminary laboratory ex-

CURRAN & HUDSON MINES

periments gave promise of success. An elaboration of this method is to crush the ore coarsely and feed it through a revolving cylindrical-shaped copper brush which removes the Carnotite incrustation from the sand grains, without breaking the latter, then screening through a seive having mesh too fine to permit the sand grains going through, thus separating the sand grains from the Carnotite.

Leaching without agitation is impossible. Carbonate of sodium, rendering insoluble the lime present in the ore as sulphate, is advantageous. Nevertheless, freely formed calcium sulphate is a great hindrance to clarification of liquors and the free washing of the pulp. The action of the acid on the clay-like substances present produces colloids, with disagreeable results. The clay present and the gases formed from the limestone form channels which are characterized by the colors left by the secondary precipitation along their course. No method depending upon difference in specific gravities may be employed.

However, a Denver concern is experimenting with low grade Carnotite ores trying to concentrate them by means of supposed difference in specific gravity of sand and Carnotite, the separation to be effected by an air blast through a linen sheet covering an apparatus resembling the Wilfley concentrating table.

It is difficult to conceive of an ore more susceptible of chemical treatment than Carnotite. In a solution of five parts water and one part c. p. sulphuric acid, 85% of the Vanadium and Uranium are in solution in 15 minutes, and the entire contents are in solution in 30 minutes.

The following is a method of alkaline leach. The ore is ground to 14 mesh, is boiled under agitation with a 10% solution of sodium carbonate until the values are in solution, as shown by the appearance of the pulp. This solution is yellow and contains the Uranium as the soluble double carbonate and the Vanadium as sodium vanadate (should there be a lower state of oxidation of either metal, as there probably will be, a preliminary oxidation would be necessary). From this solution, which is drained off, or filtered off, the Uranium is precipitated, with a solution of caustic acid as sodium uranate, which settles quickly and is filtered and dried. To the filtrate containing the Vanadium, milk of lime is added, which precip-

itates the Vanadium as calcium canadate and renders the sodium carbonate caustic, an equivalent of calcium carbonate being precipitated at the same time. The caustic solution, after filtration of the calcium vanadate, is recarbonated by the carbon dioxide from the preparation of the caustic lime and used over. This method has the advantage of using a reagent, which is indifferent to the action of carbonates of lime and iron and has also the advantage of producing a high grade Uranium concentrate.

In 1890 O. P. Fritchele, of Denver (inventor and maker of the Fritchele 100-mile electric automobile), produced 500 pounds of a compound of Vanadium and Uranium by an electrolytic-chlorine method. Samples of this compound will be examined to ascertain if the radium values remain therein.

The Ohly process treats the Carnotite with sulphuric acid and sodium carbonate in excess to precipitate iron and aluminum hydrates. The Uranium and Vanadium remains in solution in the excess of sodium carbonate. Ammonia is added to precipitate the hydrated oxide of uranium, which is subsequently ignited to uranium oxide, or sodium hydrate is added to produce sodium uranate. This method does not commend itself.

The general plan of concentration and marketing of Carnotite, recommended by Prof. A. W. Forstall, S. J., Denver, in the Twelfth Biennial Report of the Bureau of Mines of Colorado, commends itself, namely, the preparation of sulphates consisting of the sulphates of barium, calcium, lead, with radium sulphates, or Uranium and Vanadium oxides with numerous impurities.

The U. S. Bureau of Mines, Denver, under direction of Dr. R. B. Moore and K. L. Kithil, has undertaken the problem of prevention of waste and of increased efficiency in Carnotite mining; they are attacking the problem in a spirit of enthusiastic earnestness.

RADIUM EXTRACTION.

Carnotite residues, after acid treatment, may contain radium values in the form of insoluble sulphates. These are boiled with sodium carbonate solution, thus changing the values to carbonate, and after washing free from all sulphates are leached with hydrochloric acid. The mixed chlorides in solution are then purified to desired degree of concentration by fractional crystallization. The residues from the alkaline

extraction return the barium and radium values as carbonates. After washing to free the residues from sulphates, they are extracted with hydrochloric acid, and the radium and barium precipitated as sulphates. Further concentration could be undertaken by reconversion into carbonates, washing, re-extraction as chlorides or bromides and fractional crystallization.

The absorption process of Erich Ebler (Heidelberg, Germany), has for its object to isolate or separate radium, polonium, ionium, etc., by absorption by colloids, such as threads of acetyl-cellulose, or of trisulfid of arsenic, silicic acid, which colloids are concentrated by volatilization or calcination.

A very active preparation of radium was produced at the Neulenbach Radium Works (Germany) by a combined acid and alkaline fusion process which extracts the radium direct from the minerals in the form of a crude sulphate.

RADIO-ACTIVITY.

Radio-activity is the manifestation of the disintegration of the atom, a process that is spontaneous and constant. In radium this disintegration is so intensely rapid that it may be observed easily and studied: witness the isolation and determination of the physical and chemical properties of the emitted gas, known as radium emanation, a product of the transformation of radium, while the continuous production from radium of the gas helium is added evidence in support of this theory.

MARKETING OF RADIUM.

The first commercial preparations of radium-bromide were produced by the Societe Centrale de Produits Chimiques, 44 Rue des Ecoles, Paris, under the direction of Debierne.

Dr. Giesel, Chemist of the Chininfabrik, Braunsweig, Germany, first put preparations of nearly pure radium salt on the market. Rutherford notes: "Many scientific workers in this way obtained nearly pure radium bromide at a price initially of less than one-tenth of the prices to-day. The exceedingly high price of radium at the present day (£16, or about $79, per milligram of pure radium bromide), bears no relation to the cost of separation from uranium minerals. The present price is artificial, and has resulted from the comparative rarity of deposits of pitchblende or uranium minerals containing fairly high percentage of uranium. The extensive use of radium for medical purposes as well as for physical and chemical experiments, has so far absorbed the output."

In 1909 Lord Iveagh and Sir Ernest Cassel made a contract with the British Metalliferous Mines, Ltd., for 7½ grams of pure radium bromide to be supplied from the company's mines, near Grampound Road, Cornwall, at the price of about $20 per milligram.

USES OF RADIUM.

The power of radium is stupendous. Dr. Lebon has rather fancifully illustrated it by stating that the energy contained in a piece of radium no bigger than a marble would propel a train along a line four and a half times the circumference of the earth.

L. Frischauer discovered when sulphur is allowed to crystallize exposed to the action of radium, the number of centers of crystallization is greatly increased, rising to double that in specimens of sulphur, which were treated in exactly the same way, but were screened from the radium rays by lead foil.

Sauberman says:

"The inertness of radium emanation stands in direct opposition to many of its other chemical and catalytical effects, which indicate the possession of enormous energy. Not only is the emanation in a condensed condition luminous, but it causes glass, diamonds, willemite, sidotblend, kungite, and a hundred other substances, to fluoresce. Moreover, it discolors halogen salts, rock crystal, and diamonds.

"The emanation contains 75% of the total energy of the radium bromide from which it was given off. It produces thermo-fluorescence in marble, calcium manganese, and rock crystal, blackens a photographic plate as if by daylight, and accelerates the crystallization of sulphur and selenium tenfold.

"Organic substances are affected far more than inorganic. Paper becomes singed, celluloid brittle and opaque, and green leaves turn yellow, as a consequence of the change of the chlorophyll into xanthophyll. Whilst radium electrolyses water into hydrogen and oxygen, its emanation produces combination in a mixture of oxygen and hydrogen into water, even in the dark and at normal temperatures. This oxidation is unique in chemistry and is as wonderful as the decomposition of carbonic acid, first observed by Ramsay, or the change of oxygen into ozone, an effect which can otherwise only be obtained by electric currents of great intensity."

Radium has an assured place in therapeutics. The British Radium Institute (1913) reports 657 cases they treated, as follows:

Examined but not treated	38	
Recently treated and results not yet noted	41	
Received prophylactic irradation only	39	
	——	118
Apparently cured	53	
Cured	28	
Improved	248	
	——	329
Not improved	70	
Dead	85	
	——	155
Abandoned treatment		88

All cases were accepted for treatment except where the patient was actually moribund. In not a few cases marked as "abandoned," treatment was given up because the patient had been obliged to leave London, or was unable to defray the expense of repeatedly traveling from the country to the Institute.

From official government publications of Austria-Hungary, etc., it is given out that according to the experience obtained up to this day in radium therapeutics, the radium cure is particularly advisable and has been recommended in the following cases, among other authorities by:

Chronic Inflammation of the Joints; Chronic Articular and Muscular Rheumatism.	Dautzwitz, Falta, Gottleib, Gudzent, His, Langhans, Kraus, Loewenthal, Laqueur, Neusser, Noorden, Strasser, Sommer, Kemen, Winternitz, Strasburger, Schuppenhauer, Hoffman, Klemperer, Paul Lazarus.
Chronic Bronchitis, Asthma.	Barthels, Bulling, Langhans, Nagelschmidt.
Chronic Myocarditis.	Kemen, Loewenthal.
Chronic Eczema.	Bayet, Trautwein.
Chronic Inflammations.	Loewenthal.
Chronic Women's Diseases; Climacterical Complaints.	Fabre, Gudzent, Kemen.
Chronic Empyema.	Bartels.
Chronic Exsudative Pleuritis.	Salzmann.

Uric Gout and similar disorders:	Dautwitz, Falta, Gottleib, Armstrong, Kable, Gudzent, Heiner, Kemen, Langhans, Loewenthal, Mesernitzki, Neusser, Noorden, Klecki, Bergell, Schmidt, Deutelmoser, Paul Lazarus, Weidenbaum, Brasck.
Ischia, Neuralgia, Neuritis.	Dautwitz, Falta, Gottleib, Heiner, Langhans, Loewenthal, Neusser, Noorden.
Nephritis.	Armstrong, Grin, Eichholz, Bergell.
Sharp pains from Meseraica (spinal complaint).	Gottleib, Selka, Stern, Strasser.
Sleeplessness.	Furstenberg, Heiner, Loewenthal.
Sexual Neurasthenia and similar illnesses.	Gottleib, Heiner, Laqueur, Strasser, Walde.
Arterio-sclerosis (signs of old age.	Noorden, Eichholz, Grin, Armstrong, Schiff.
Swelling, neoplasma.	Bavet, Czerny, Degrais, Exner, Heinatz, Holzknecht, Nabmacher, Wickham.

Dr. S. Saubermann, of Berlin, summarizes the physiological effects of radium emanation (which is an oxidizing agent increasing the activity of the body's ferments) as follows:

1—Radium promotes the growth and multiplication of healthy cells, while morbid cells decay;

2—Radium increases the secretion of urine;

3—Radium stimulates the activity of the digestive tract, both in the stomach and intestines, and lessens chronic constipation;

4—Radium increases the excretion of uric acid in the urine;

5—Radium dilates, or expands, the blood vessels by excitation of the vaso-motor nerves;

6—Radium diminishes the viscosity of the blood, i. e., thins the blood;

7—Radium lowers the blood pressure;

8—Radium increases metabolism, especially of hydrocarbons, as proved by measurements of the amount of carbonic acid excreted;

9—Radium soothes the nerves and relieves insomnia;

10—Radium increases sexual activity;

11—Radium modifies the constitution of the blood, resulting in real and lasting improvement in simple anæmia;

12—Radium stimulates the activity of the liver.

The various salts, etc., of Radium are as follows:

Radium Bromide ($Ra\ Br_2\ 2H_2O$) contains 53.6% radium element, Ra.

Radium Chloride ($Ra\ Cl_2$) contains 76.1% Radium element, Ra.

Radium Carbonate ($Ra\ CO_3$) contains 79.0% Radium element, Ra.

Radium Carbonate contains 79.0% Radium element, Ra.

The radio-activity of Radium element, Ra., calling activity of Uranium unity, is 3,731,000; of Radium bromide, 2,000,000; etc.

1 Milligram Radium element	= 1.87	mgs. Radium Bromide
	= 1.42	mgs. Radium Sulfate
	= 1.31	mgs. Radium Chloride
	= 1.265	mgs. Radium Carbonate

Wm. Allen Pusey, of the University of Chicago, observes: "What bio-chemical processes are set going by Radium or by the familiar forms of actinic energy, we are in no position to say. From experiments with radium on eggs, Schwartz proposed that all of the effects of radium on tissues were due to decomposition of lecithin. Hussakof suggests from experiments of Willcock, Zuelzer and Kornicke that oxygen in some not understood way plays a part in the process. There is every reason to believe that the process is not explicable in any simple chemical reaction. Radium rays do not produce an immediate effect upon living tissues, similar to the reduction of silver salts, for example. They have an effect upon life processes of the cells and these after a comparatively long time produce the results recognized as radium reaction. In other words, the process is a vital process and one doubtless involving all of the chemical complexity of cell life itself."

The proper development of the American Carnotite industry is dependent largely upon the establishment of a radium works in New York, Philadelphia, Baltimore or Denver, that will absorb the ore output of the independent Carnotite mine operators, at a reasonable price. There is little business risk in forming such a radium business, because radium extraction from Carnotite is being done profitably and regularly in Europe; the new Underwood tariff will lower greatly the price of chemicals used in the extraction process; the American use of one of these European Radium-Carnotite extraction processes may be acquired, together with experienced radium chemists to supervise works' operations; the use of radium is increasing rapidly in America, and physicians, surgeons and scientists, schools and colleges, are experimenting constantly to extend its use.

Late in September, 1913, the American Radium Institute was formed, principally by Dr. Howard A. Kelly, the famous genaecologist, of 1418 Eutaw Place, Baltimore, and James Douglas, of Phelps, Dodge Co. (copper), 99 John Street, New York City. It is the intention to make 5 grams of radium bromide from Colorado Carnotite, in a laboratory in Denver. The purpose of this Institute is similar to that of the British Radium Institute. Its home will be Baltimore, Maryland.

The Committee for an International Radium Standard gives out the following:

1 CURIE = quantity of radium emanation (0.60 cubic millimeters at 0° C. and 760 mm. pressure) in equilibrium with 1 gram of radium element.

This quantity gives a saturation current in an ionization chamber of indefinite dimensions, of 2.67 million electrostatic units (0.89 milliampere). One Curie of emanation per liter would equal a concentration of 2670 million Mache units.

1 MILLICURIE = quantity of radium emanation in equilibrium with 1 milligram (1 thousandth of a gram) of radium element.

1 MICROCURIE = quantity of radium emanation in equilibrium with 1 microgram (1 millionth of a gram) of radium element. 1 microcurie per liter equals a concentration of about 2700 Mache units.

1 MILLIGRAM MINUTE = quantity of radium emanation produced in 1 minute by 1 milligram of pure anhydrous radium bromide. This quantity is 0.073 microcurie and would give per liter a concentration of about 180 Mache units.

1 ELECTROSTATIC UNIT (e. s. u.) current measure 3.33×10^{-10} (0.000000000333) ampere.

1 MACHE UNIT (m. u.) = saturation ionization current due to radium emanation from a liter of solution of gas expressed in electrostatic units multiplied by 1000.

Radium Products Company

CABLE ADDRESS COLORADIUM.

NEW YORK, N. Y. BALTIMORE, MD.
DENVER, COLO. PLACERVILLE, COLO.

Carnotite ore mines in Long Park, Paradox Valley, Hieroglyphic Canon, Eagle Basin, Ore Atkinson Creek, Lion Creek, La Sal Creek, Roc Creek, Montrose County, and Big Canon, McIntyre District, San Miguel County.

RADIUM PRODUCTS COMPANY,

Placerville, Colo., U. S. A.,

Mine and Sell Carnotite Ore.

Terms of Sale:

WEIGHT: Avoirdupois, 16 ounces to pound, 2000 pounds to ton; as shown on Through Export Bill of Lading if shipment is so made; otherwise, as shown on Certificate of Sampling.

INSURANCE: To be effected by, for and at expense of Buyer.

DELIVERY: Delivery shall be completed by Seller free on board railroad cars on Samplers' Railroad Siding after the ore has been sampled.

SAMPLING: Sampling by Henry E. Wood Ore Testing Co., Denver; Chamberlain & Dillingham Ore Co., Denver; American Smelting & Refining Co., Pueblo, or by other public sampler, at option of Seller.

ASSAYING: By Ledoux & Co., 99 John St., New York, N. Y., or by U. S. Bureau of Standards, Washington, D. C., or by other assayer that may hereafter be agreed

PAYMENT: Buyer shall establish a banking credit, through his home bank, with the bank designated by the Seller, and in manner satisfactory to Seller's Bank and to Seller. Seller may make Sight Draft upon the Buyer, through Seller's bank, for the total amount of the invoice, and shall attach to said Sight Draft the following documents, to wit:

1: Through Export Bill of Lading, in duplicate, properly endorsed, or proper Railroad Bill of Lading;

2: Certificate of Sampling;

3: Certificate of Assay;

4: Certified copy of Invoice.

It is specifically understood and agreed by Buyer and Seller that these documents are final and conclusive.